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Information about Sediment Remediation

The Passaic River Community Advisory Group (CAG) requested that the Technical Assistance Services for Communities (TASC) program provide information about river sediment remediation. The CAG is interested in potential remedies that may be used to clean up the Passaic River. The CAG is particularly interested in understanding options for different dredging techniques and how resuspension of contaminated sediments may be minimized. The CAG also requested information about sediment remediation projects similar to the dredging proposed in the U.S. Environmental Protection Agency's draft Focused Feasibility Study for the Lower Passaic River Study Area.

This report is organized into the following sections:

- Table 1: Sediment Dredging Options
- Table 2: Sediment Disposal Options
- Table 3: Sediment Cleanups Similar to the Proposed Passaic River Cleanup

The information provided in this document does not necessarily reflect the policies, actions or positions of the EPA.

Table 1: Sediment Dredging Options

Category and Description	Advantages	Disadvantages
Mechanical Dredges: Overview		
Mechanical dredges remove material by scooping it from the bottom of a water body and then placing it onto a waiting barge or into a disposal area. **Example cost at sediment megasite: $1,870 per cubic yard** (overall cost, including dredging, for Hudson River Phase I according to GE).[4] Note: Dredging typically accounts for 10-20 percent of overall project cost.[5] Cost of dredging depends on site characteristics, such as depth of water, amount of debris, degree of contamination).	• Rugged; can remove hard-packed materials. • Can remove debris and debris-laden sediments. • Can operate in tight areas. • Efficient for transport by barge for long haul distances. • Can remove sediments at nearly in situ density, with minimal requirements for managing excess water. • Can operate in deep water. • Can use different types of buckets (e.g., switching from box cut buckets to toothed buckets to smaller buckets).[1]	• Can resuspend contaminated sediments. • If bucket does not close completely (e.g., due to large debris), sediment will escape as bucket is lifted. • Production rates are lower than comparably sized hydraulic dredges. • Normally requires barges for transport of the dredged sediments. • May require re-slurry of sediment prior to treatment.[1] • Does not dredge continuously like pipeline dredges. • May need added controls when handling contaminated sediments.[2]
Mechanical Dredges: Types		
<u>Conventional Clamshell</u> A clamshell is a mechanical device with two jaws that are used to pick up sediment.	• See information for mechanical dredges.	• Releases some sediment throughout the water column.[1]

Category and Description	Advantages	Disadvantages
Enclosed Bucket A clamshell that seals shut to contain contaminated sediment.	• Uses sealed bucket to contain contaminated sediment.	• Water captured in the bucket must then be handled on the barge or at the disposal area.[1]
Wire-Supported Bucket Support system for dredging bucket is wire instead of a fixed-arm.	• See information for mechanical dredges. • Can be deployed greater depths than fixed-arm dredges.[3]	• Hard to control on slopes and can contribute to the formation of layers of residual contamination.[1] • Less vertical and horizontal operating accuracy than fixed arm.[3]
Hydraulic Dredges: Overview		
Hydraulic dredges remove material by sucking up water and loose solids through a large suction pipe and discharging the material into an onboard containment area, onto a waiting barge or into a disposal area. **Example cost at sediment megasites: $220-1,670 per cubic yard** (overall project costs, based on 2006 survey of sediment megasites).[6]	• Capable of excavating most types of materials with higher production rates than comparably sized mechanical dredges. • Capable of dredging on a near-continuous basis, with higher production than similarly sized mechanical dredges. • Capable of pumping material directly by pipeline to confined disposal facilities, geotubes, or mechanical dewatering and treatment facilities. • Capable of switching dredgeheads for different sediment types.[1]	• Resuspended sediment is left behind as a "spillage layer."[1] • Excavation is less precise than with other dredges. • Has difficulty dredging steep banks and consolidated materials.[2] • Difficulty with debris (e.g., plugging, inability to capture material, suction head gets pushed off intended location). • Generates a large quantity of excess water, leading to potentially high cost of sediment dewatering and water treatment.[1]
Hydraulic Dredges: Types		
Cutterhead Pipeline Dredge A mechanical device with rotating blades or teeth to break up or loosen sediment so that it can be sucked through the dredge.	• Can excavate most materials. • Can pump directly to a disposal site. • Can dredge almost continuously. • Can dredge some types of rock without blasting.[2]	• Limited capability in rough weather. • Difficulty with coarse sand in swift currents. • Is usually not self-propelled. • The necessary pipeline can be an obstruction to navigation. • Removal efficiency is diminished when handling debris in sediment.[2]

Category and Description	Advantages	Disadvantages
Self-Propelled Hopper Dredge Ships with large hoppers, or containment areas.	• Can operate in rough water. • Can move quickly to a job site under its own power. • Dredging operation does not interfere with other traffic. • Work progresses quickly. • Economical for long haul distances.[2]	• Limited to work in deep waters. • Cannot dredge continuously.[2]

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Table 2: Sediment Disposal Options

Category and Description	Advantages	Disadvantages
<u>Confined Aquatic Disposal (CAD) Cells</u> Stores contaminated sediment in a depression at the bottom of a river, lake or harbor. **Example cost: $56 per cubic yard.**[15]	• Locations are often near the dredging site.[1] • Can usually be put in with conventional equipment and minimal transport and rehandling of sediment.[1] • Experience with CAD cells is increasing. CAD cells are located in six New England harbors.[2]	• Can face community opposition due to concerns about effectiveness of long term maintenance, potential for recontamination, etc. • Propeller action could collapse cell walls or disturb the cap. • Requires monitoring to ensure cap integrity.
<u>Open Water Placement and Capping</u> Similar to a CAD when capping is used, but contaminated sediment is placed further away from shore in deeper water. **Least expensive disposal option.**[1]	• Permanent removal of material from the dredged location with no impact to adjacent land uses or navigational concerns.[3]	• Placement of contaminated sediment in open water may not be allowed by the Marine Protection, Research and Sanctuaries Act.[1] • Dredging operation is usually slower compared to using other disposal methods due to vessel capacity limits and transport of the material offshore.[3]

Category and Description	Advantages	Disadvantages
Confined Disposal Facility (CDF) A containment area designed to receive dredged material. It may be designed as near shore (partly in water) or an island (completely surrounded by water). **Example cost: $115 per cubic yard.**[14]	• Can create developable land to support economic growth in some locations.[4,6] • Reduced costs and reduced need for transport of dredged material compared to many other disposal alternatives.[5]	• Acquiring nearshore property may be difficult and costly. • Designing, permitting and building new facilities is costly.[5] • Environmental impacts, particularly in nearshore (wetland) areas, may not be resolvable.[5] • Can face significant community opposition.[5]
Upland CDF or Landfill A designed containment area above the water (upland) that receives dredged material. **Example cost: $86 per cubic yard** for rail transport and disposal. $48 per cubic yard for dewatering.[13]	• Contaminated material is moved away from the local community.	• Location for offloading and dewatering needed. • Transport to a distant facility can be costly.[7] • Overland transport of contaminated sediment increases exposure risks. • Increased truck traffic may be a concern for local residents.
Treatment – Thermal Desorption A method that uses heat to evaporate, remove and capture (if necessary) contaminants from sediment.[8,9] Temperatures ranging from 200°F to 1000°F can be used, depending on the contaminants present.[9] **Example cost: $101 per cubic yard.**[10]	• Effective for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCBs) and pesticides.	• Does not remove most metals.[8] • Overland transport of contaminated sediment to a treatment location or finding property to set up local treatment facility is needed. • May require a large area for operations, including storage of contaminated sediment for treatment.[9]

Category and Description	Advantages	Disadvantages
Treatment – Soil Washing The use of solvents to extract contaminants from contaminated sediment. **Example cost: $53 per cubic yard.**[10] Estes et al. estimated a cost of **$41 per cubic yard** for the BioGenesis sediment washing technology.[11]	• Effective for PAHs, PCBs, and metals. • Effective with coarse sand and gravel sediments.	• Marginally applicable for clays and silts.[9]
Treatment – Solidification / Stabilization The application of materials, such as Portland cement or fly ash from coal fired combustion equipment, to solidify and bind contaminants to soil particles so that the contaminants do not leach out after disposal or beneficial use. **Example cost: $94-144 per cubic yard.**[10]	• Effective for metals. • Widely used treatment technology. •	• Limited effectiveness against organics and pesticides.[9, 10] • Variable effectiveness for PAHs, PCBs and pesticides.
Treatment – Vitrification The use of high temperatures (about 2900°F) to destroy organic contaminants and change contaminated sediment to a glass-like material. **Example cost: $71 per cubic yard** for one vitrification technology.[11] **Example cost:** A 1996 cost projection was **$1,379 per cubic yard** for sediments with high moisture content. The vendor estimated that dewatering and then vitrifying would reduce the cost by about half.[12]	• Destroys most organic contaminants, immobilizes metals.[10]	• Energy intensive. • May not be practical for very wet material. • Opposed by some community members at Passaic site.

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Table 3: Sediment Cleanups Similar to the Proposed Passaic River Cleanup

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
Lower eight miles of the Passaic River New Jersey	Dioxins, PAHs, PCBs, pesticides and metals Planned dredging of 4.3 to 9.6 million cubic yards of sediment	The 2007 draft Focused Feasibility Study (FFS) describes cleanup alternatives considered for the lower eight miles of the Passaic River. The volume of sediment to be removed ranges from 1.2 to 11 million cubic yards. Thermal treatment is recommended for either 1.2 or 1.7 million cubic yards of contaminated sediment (2007 FFS, p. 15). Thermal treatment uses high temperatures to remove contaminants from sediment. Types of thermal treatment discussed in the 2007 FFS include thermal desorption, thermal destruction and vitrification (2007 FFS, pp. 3-16 and 3-17).[1] In October 2012, the EPA provided a summary of the revised FFS, which is not yet available for review. The summary indicates that the volume of sediment to be removed ranges from 4.3 to 9.6 million cubic yards, depending on the remedial alternative selected. Alternatives include: a) deep dredging all fine-grained sediments in the FFS study area (9.6 million cubic yards) and placing two feet of backfill; and b) dredging enough fine-grained sediment (4.3 million cubic yards) to ensure that an engineered cap can be put in place without causing additional flooding and to allow for a navigation channel in river miles 0 to 2.2. Construction duration is estimated at 11 years for deep dredging and six years for dredging with an engineered cap. Alternatives for disposing of dredged sediment include CAD, off-site disposal and local treatment with beneficial use. Local treatment alternatives are thermal treatment, sediment washing and solidification/stabilization, or a combination of sediment washing and solidification/stabilization.[2]			

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
Cumberland Bay PCB Dredging Project Cumberland Bay, New York	PCBs in inland lake 195,000 cubic yards of sediment dredged	Cumberland Bay is located in a small part of the west bank of Lake Champlain in New York. Removal of PCB-contaminated sediment took place from 1999 to 2000 using a **hydraulic dredge**. Sediments were conveyed to a shore-side processing facility where they were mechanically dewatered. **Dredging was performed using two horizontal auger dredges within sheet piling and turbidity barriers.**[3] • Dredged 195,000 cubic yards from 34-acre site.[4] • Debris (logs, wood chips, rocks) and a heterogeneous substrate caused dredging problems.[4] • Many areas found where PCB removal was incomplete due to the presence of debris.[4] • Bubbling up of gas near a dock area during dredging caused sludge to float to the surface.[4] • After dredging, 51 sediment samples indicated that PCB concentrations in sediment were significantly lowered.[4] • PCBs averaging 6.8 milligrams per kilogram were still present following dredging.[4]	Full scale	PCB concentrations in sediment were significantly lowered. Reduction in risk was not quantified, because risk-based numeric remediation goals were not selected for the site.	Much less sediment volume to remove. Inland lake rather than a river. Similar PCB concentrations (up to 13,000 parts per million).[3]

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
Hudson River Eastern New York	PCBs contaminated 2.65 million cubic yards of sediment 283,000 cubic yards of sediment dredged Planned dredging of additional 2.4 million cubic yards of sediment	The Hudson River PCBs Superfund site encompasses a nearly 200-mile stretch of the Hudson River in eastern New York from Hudson Falls to the Battery in New York City. It includes communities in 14 New York counties and two counties in New Jersey.[5] • *Phase 1:* Removal of 283,000 cubic yards of PCB-contaminated sediment from a six-mile stretch of the river from May to November 2009.[5] • *Phase 2:* Removal of 2.4 million cubic yards of sediment. Started in June 2011, with dredging season from May to October. Estimated duration: five to seven years.[5] • **Mechanical dredging and clamshell buckets place dredged sediment into barges.** They take the sediment to a dewatering and sediment processing facility.[5] • Sediment is transported by train to approved landfill facilities.[5]	Full scale Phase 1 provided data for Phase 2 planning	During Phase 1, repeated dredge passes and prolonged exposure of sediments resulted in increased PCB resuspension and release. A peer review panel recommended changes to reduce resuspension of sediment for Phase 2 dredging, as well as annual review of data from each subsequent dredging season.[6]	Half the volume of sediment as the lowest EPA volume estimate for the Passaic River.

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
Lower Fox River and Green Bay Superfund Site Northeastern Wisconsin	PCBs in river 2.7 million cubic yards of sediment dredged so far.[20]	Since 2009, about 2.7 million cubic yards of sediment have been dredged.[20] **The dredging is conducted using hydraulic dredges; mechanical dredging can be used in places where hydraulic dredging is not possible.** About one million tons of dried sediment have been taken to Hickory Meadows Landfill near the town of Chilton. About 62 acres of sediment were covered with sand. Fifty-two acres were capped with sand and rock. A final seven-mile stretch of river is expected to be remediated in 2017.[7] <u>2009 Five Year Review</u> Operable Unit (OU) 1 is the first six upstream miles of the Lower Fox River. OUs 2 through 5 are in the downstream 12 miles of the Lower Fox River.[8] For all sediments with PCB concentrations greater than 1 part per million, the remedy included: • Dredging and off-site disposal. • Engineered cap of sand and armor stone (thickness varies by OU). • Sand cover for areas with PCB concentrations less than two parts per million and where the contaminant interval is less than 6 to 8 inches in thickness.[8] • Long-term monitoring and maintenance. Monitoring will consist of monitoring fish, surface water, cap integrity and containment effectiveness. If cap integrity were compromised, either cap repair or removal (along with removal of underlying contamination) would take place.[8]	Full scale: 2004-present Pilot scale: 1999-2000 (82,000 cubic yards) Pilot scale: 1998-1999 (8,200 cubic yards)	At the Fox River Sediment Management Unit 56/57 sites, dredging-related releases resulted in an increase in downstream dissolved-PCB concentrations of about 59 percent.[9] Steep side slopes, debris, and underlying clay made it difficult to remove contaminated residuals in some areas.[8, 9]	Less than half the volume of sediment as the lowest EPA volume estimate for the Passaic River.

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
New Bedford Harbor Site New Bedford, Massachusetts	PCBs in harbor 230,000 cubic yards of sediment dredged Planned dredging of an additional 670,000 cubic yards of sediment	The 18,000-acre site is an urban tidal estuary with sediments highly contaminated with PCBs and heavy metals. The site is being addressed in four stages: initial actions and three long-term remedial phases focusing on a hot spot area, upper and lower harbor areas, and the outer harbor Buzzards Bay area. • A 5-acre hot spot was dredged in 1994-1995 and 14,000 cubic yards of sediment was removed.[10] • Since 2004, **hydraulic dredging** has been done using a network of dredges and pipelines to move sediment to dewatering facilities on shore. Debris is removed prior to dredging. The dredged material is filtered and dewatered.[10] • Dried sediment is shipped to a landfill in Michigan. The water is treated and discharged back to the harbor.[10] • A CAD cell will be built in the harbor to hold 300,000 cubic yards of the contaminated sediment.[10] • So far, 230,000 cubic yards of sediment have been dredged. A total of 900,000 cubic yards will be dredged.[10] • The EPA detected increased hydrogen sulfide concentrations in a dredged sediment handling facility and changed the operation to reduce concentrations to safe levels.[11] Vitrification was deemed impractical to use at the site because of the sidestream wastes, long processing time and high cost.[12]	Full-scale hot spot removal in estuary, 1994-1995 Full-scale hydraulic dredging since 2004	For the 2004 project, full-scale dredging cost about $800,000 per week.[11] The 1994-1995 hot spot removal included extensive monitoring. A long-term environmental monitoring plan has been in place since 1993.[10] Dredging may continue over 25 years. The rate of recovery and time to achieve remedial goals after long-term exposure to remedial dredging are not known.[11]	Less than a fourth of the volume of sediment than the lowest EPA volume estimate for the Passaic River.

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
New York/New Jersey Harbor New York/New Jersey	Metals, dioxins, PAHs and PCBs. Navigational dredging of tens of millions of cubic yards of sediment	The New York/New Jersey Harbor is a major commercial shipping port and must be dredged to maintain navigability. **Mechanical and hydraulic (hopper) dredges are used.**[13] Due to contaminatio n concerns, federal regulations restrict ocean disposal of sediments dredged from the harbor. Land-based disposal options are required.[14] Contaminated sediment was mixed with Portland cement and used as structural fill and landfill cover, with over 1.5 million cubic yards reported treated and used.[14, 15]	Solidificat ion/ stabilizati on pilot test led to full-scale treatment	Beneficial reuse of sediment.	Reports do not specify the contaminant concentrations in the treated sediment. It is uncertain if the same treatment could be used for Passaic River sediments. Similar solidification / stabilization technology for sediment from the Passaic River looked promising in one study.[16]

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
Urk Harbor Urk, The Netherlands	Oil, PCBs, heavy metals Maintenance dredging of 90,000 cubic yards	**Mechanical dredging was used** (articulated arms with specialized environmental buckets). Suction dredging was not possible due to the large amount of debris in the sediment. Dredged sediments were loaded onto barges and transported 11 miles to a disposal area. A rotating sieve drum removed debris, which was sent to a landfill. The sediments were then sent via pipeline to sedimentation basins, where the sand was separated out. The contaminated material was then placed in a confined disposal facility.[17] Project conducted in 2002-2003.		Disposal costs at the confined disposal facility were one-tenth of what the cost would have been to use a landfill.	Dredging was of a harbor, rather than a river. Much smaller volume dredged than proposed for Passaic.
Near Prince Rupert, British Columbia, Canada	PCBs 65,000 cubic yards	This project was conducted in 2004 to remove PCBs released from a transformer in 1977. Low-turbidity **hydraulic dredge** with a horizontal auger attachment removed over 98 percent of the estimated 560 pounds of PCBs released in 1977. The dredged sediment was dewatered using four bottom-draining dewatering cells, three sequential water settling ponds, and one clarifier for water polishing.[18] Cost: $10 million ($US) including disposal ($154 per cubic yard)		Avoided resuspension.	Dredging was of a harbor, rather than a river. Much smaller volume dredged than proposed for Passaic.

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup
Esquimault Graving Dock Esquimault, British Columbia, Canada	Metals, PCBs, PAHs 200,000 cubic yards	Dredging is planned for 2013-2014. **Mechanical dredging** (marine clamshell) will be used. Dredged sediments will be dewatered on an on-site water treatment barge. The material will then be barged to an off-load facility, where it will be loaded onto trucks for transport to an off-site landfill for disposal.[19] Cost: $37 million (US$) ($185 per cubic yard)			Dredging was of a harbor, rather than a river. Much smaller volume dredged than proposed for Passaic.

Site	Contaminants / Sediment Volume	Remedy	Pilot Tests	Advantages or Disadvantages	Similarity to Passaic River Cleanup

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Contact Information

Skeo Solutions Project Manager
Kirby Webster
434-975-6700 Ext. 281
kwebster@skeo.com

Skeo Solutions Technical Advisor
Hagai Nassau
434-975-6700 Ext. 252
hnassau@skeo.com

Skeo Solutions Technical Advisor
Terrie Boguski
434-975-6700 Ext. 266
tboguski@skeo.com

Skeo Solutions Work Assignment Manager
Krissy Russell-Hedstrom
434-975-6700 Ext. 279
krissy@skeo.com

Skeo Solutions Director of Finance and Contracts
Briana Branham
434-975-6700 Ext. 232
bbranham@skeo.com

Skeo Solutions TASC Quality Control Monitor
Eric Marsh
434-975-6700 Ext. 276
emarsh@skeo.com